

# The High Latitude Geospace System

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CEDAR Grand Challenge Workshop, Final Report

# The High-latitude Geospace System

Earth's magnetosphere, ionosphere, and thermosphere respond as a coherently integrated *system* to the impinging solar wind. This 'system science' view provides a path toward deeper understanding and improved prediction.

Nowhere is the systems approach more important than at polar latitudes, where solar wind power enters the geospace system through a cascade of processes that are challenging to capture observationally or through a single model.

Recent years have witnessed the rapid expansion of sensors deployed to the geomagnetic polar regions. These measurements are being supported by an increasingly sophisticated suite of models and space missions.

Efforts to reconcile these perspectives have called into question our understanding of four key areas:

- 1) energy transfer and dissipation in the geomagnetic polar regions
- 2) sources and impacts of instabilities and turbulence
- 3) role of extreme plasma gradients on magnetosphere-ionosphere coupling
- 4) mechanisms of high-latitude plasma escape.

# Infrastructure Contributions

*Improved sampling (coverage, density, capabilities)*

## Observational

- TREx - Donovan
- RISR - Varney, Gillies
- AMPERE - Anderson
- Aurorasaurus - Case, MacDonald
- Rocket Program - Clemens
- Antarctic infrastructure - Gerrard
- SWARM mission - Knudsen
- GNSS - Datta-Barua

## Modeling

- Transport Modeling (GEMINI) - Zettergren
- Plasma Simulation - Oppenheim
- ISR Simulation (SimISR) - Swoboda
- I-T Modeling (GITM) - Ridley
- Assimilative modeling (AMIE-2) - McGranaghan
- Conductivity Estimation - Kaeppeler

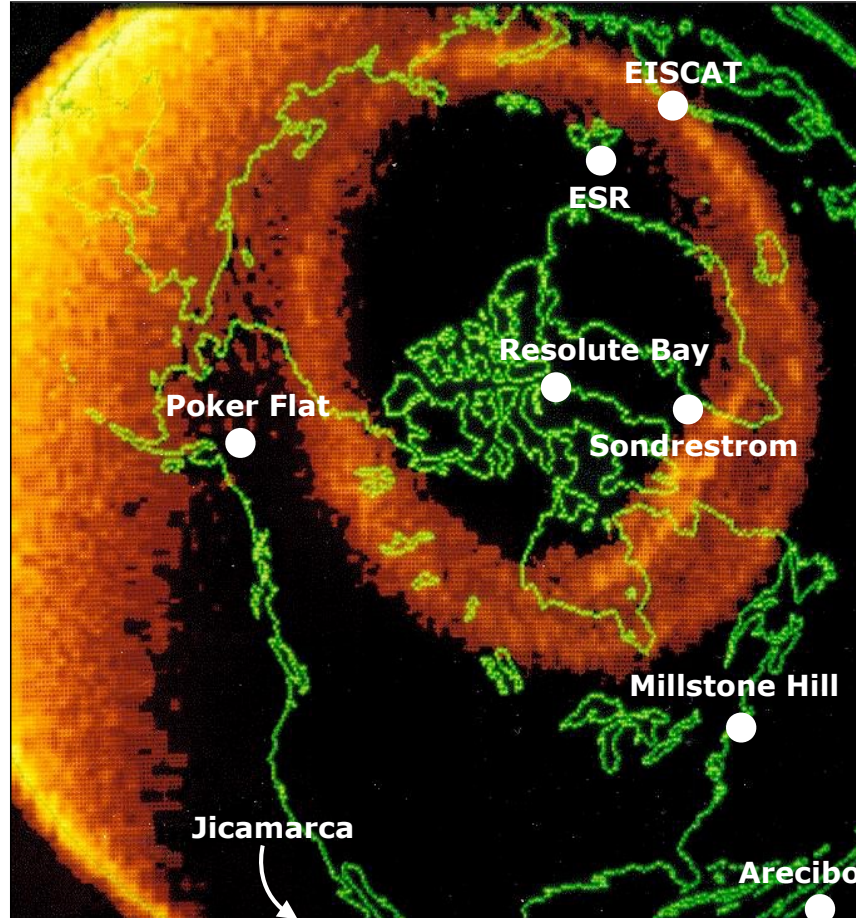
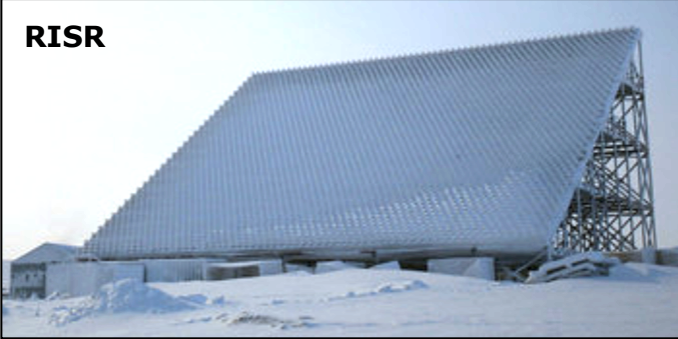
# Science Contributions

*Use of models and intuition to reconcile measurements from different locations, times, platforms, sensors*

- Topside and Ion upflow - Burchill, Sojka, Varney
- Plasma patch dynamics - Y. Zou
- Auroral omega bands - J. Liu
- Reconnection - Perry, Dahlgren, Carlson, Semeter
- Polar electrodynamics - St.-Maurice
- Polar cap-aurora interaction - S. Zou, Nishimura, Lyons
- Flows and Joule Heating - Y. Huang, C. Huang, Horvath
- I-T and Neutral Dynamics - Wu, Lotko, C. Lee, Dhadly
- Substorm onset - Gallardo-Lacourt
- Polar cap potential saturation - Clauer
- Magnetotail processes - Sivadas

# Incoherent Scatter Radar (ISR)

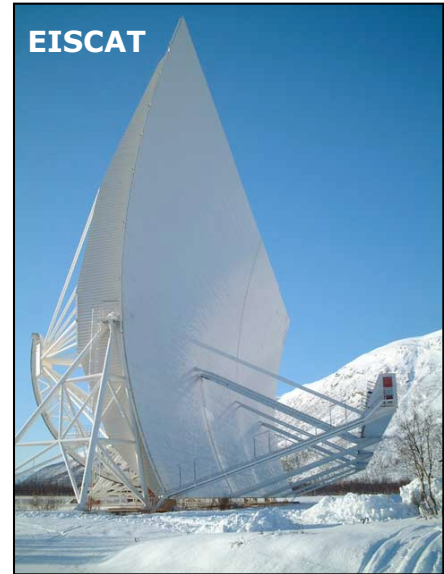
RISR



ESR



EISCAT



PFISR



Jicamarca



Arecibo

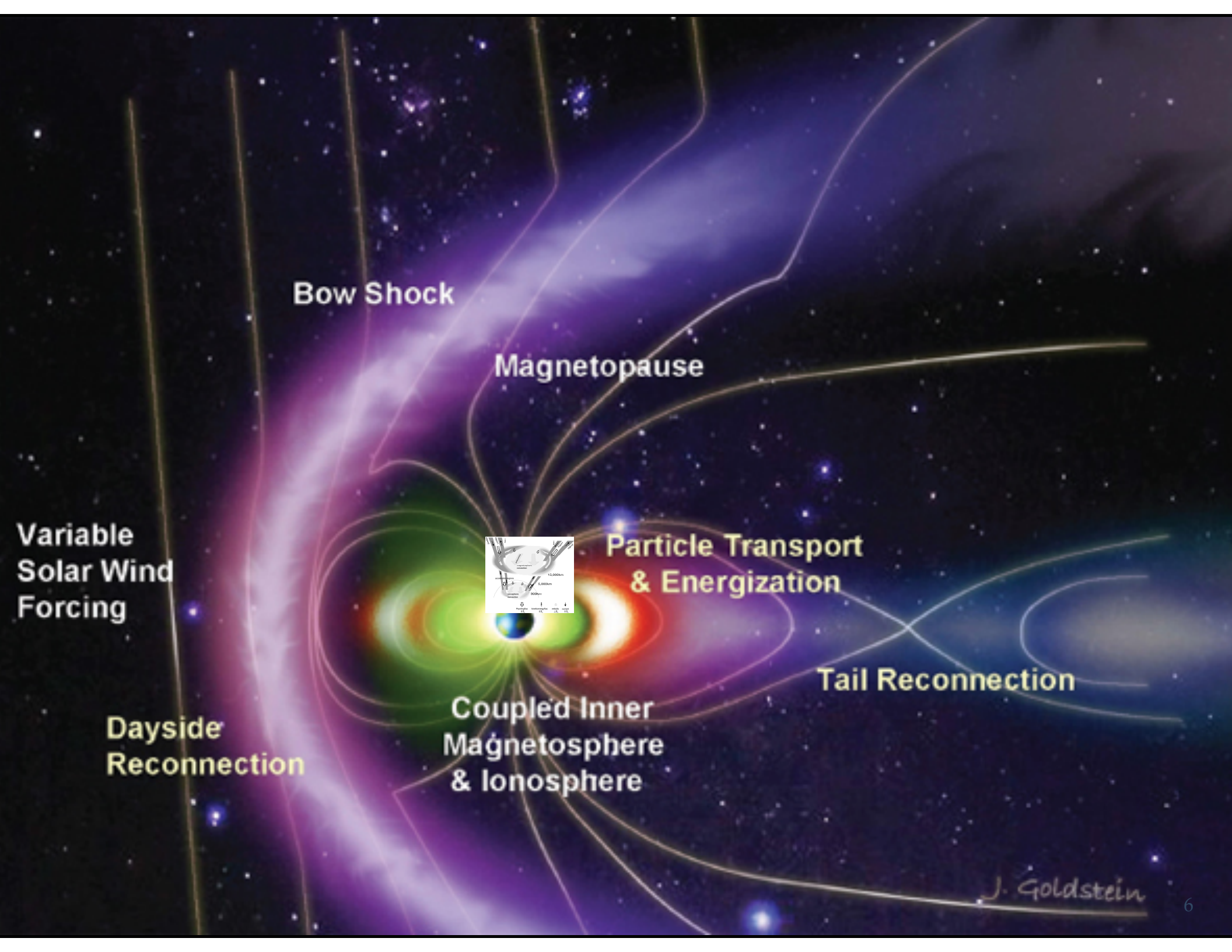


Millstone Hill



Sondrestrom





**Bow Shock**

**Magnetopause**

**Particle Transport  
& Energization**

**Tail Reconnection**

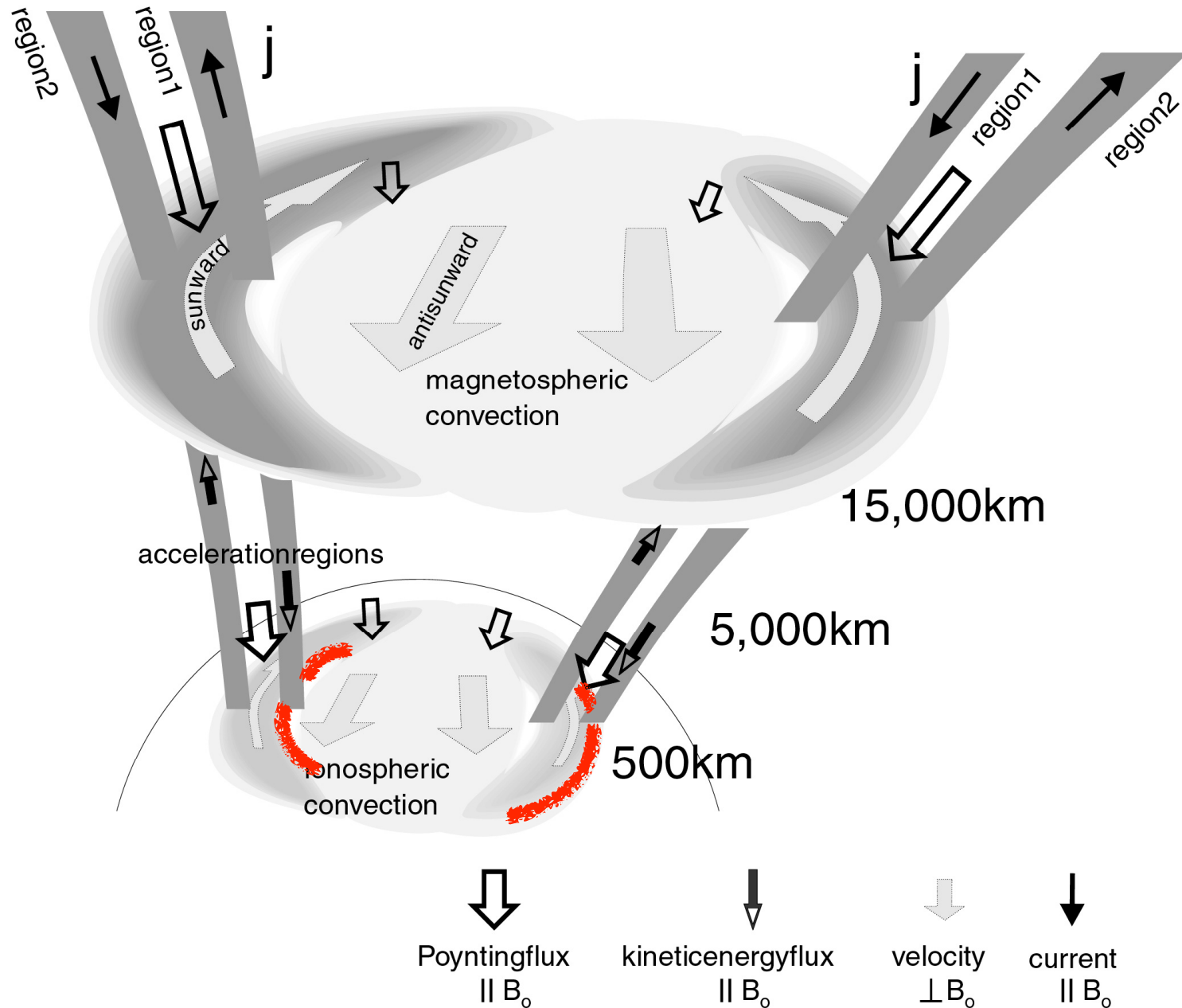
**Coupled Inner  
Magnetosphere  
& Ionosphere**

**Variable  
Solar Wind  
Forcing**

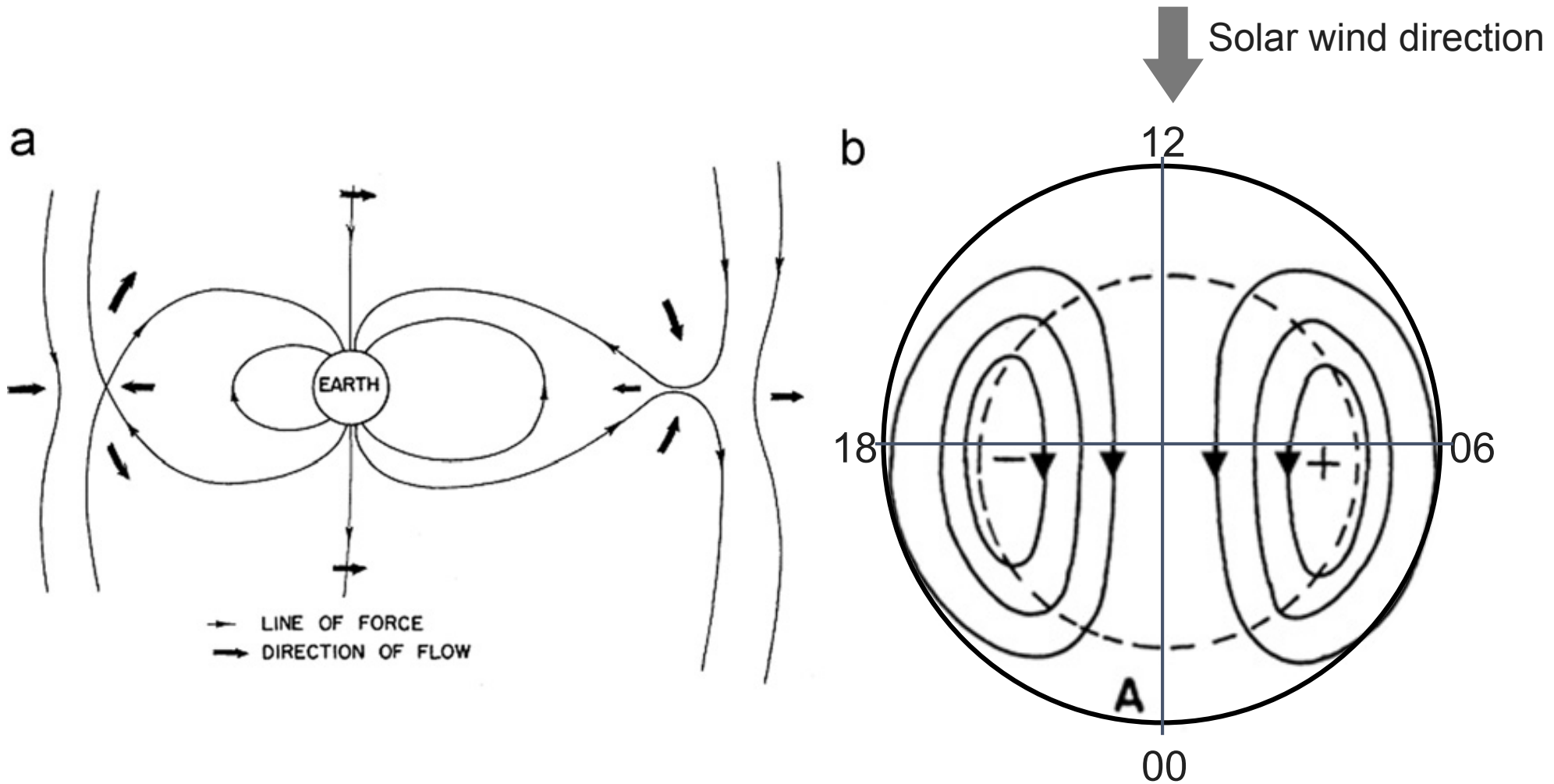
**Dayside  
Reconnection**

*J. Goldstein*

# Ionosphere as a projection of the magnetosphere



# The Dungey Cycle

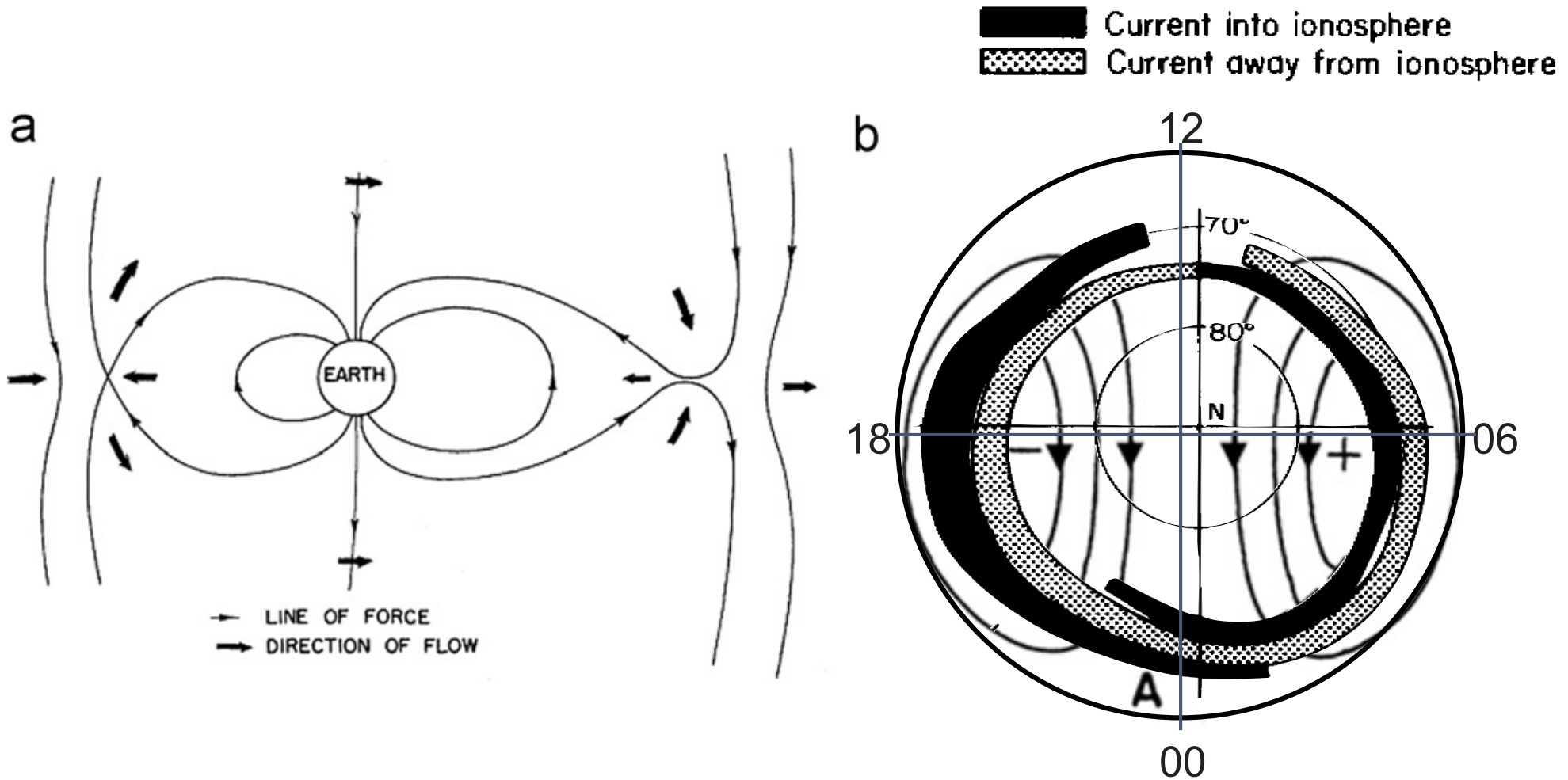


**Reconnection is a dominant driver of magnetospheric convection**

*Dungey, 1961*



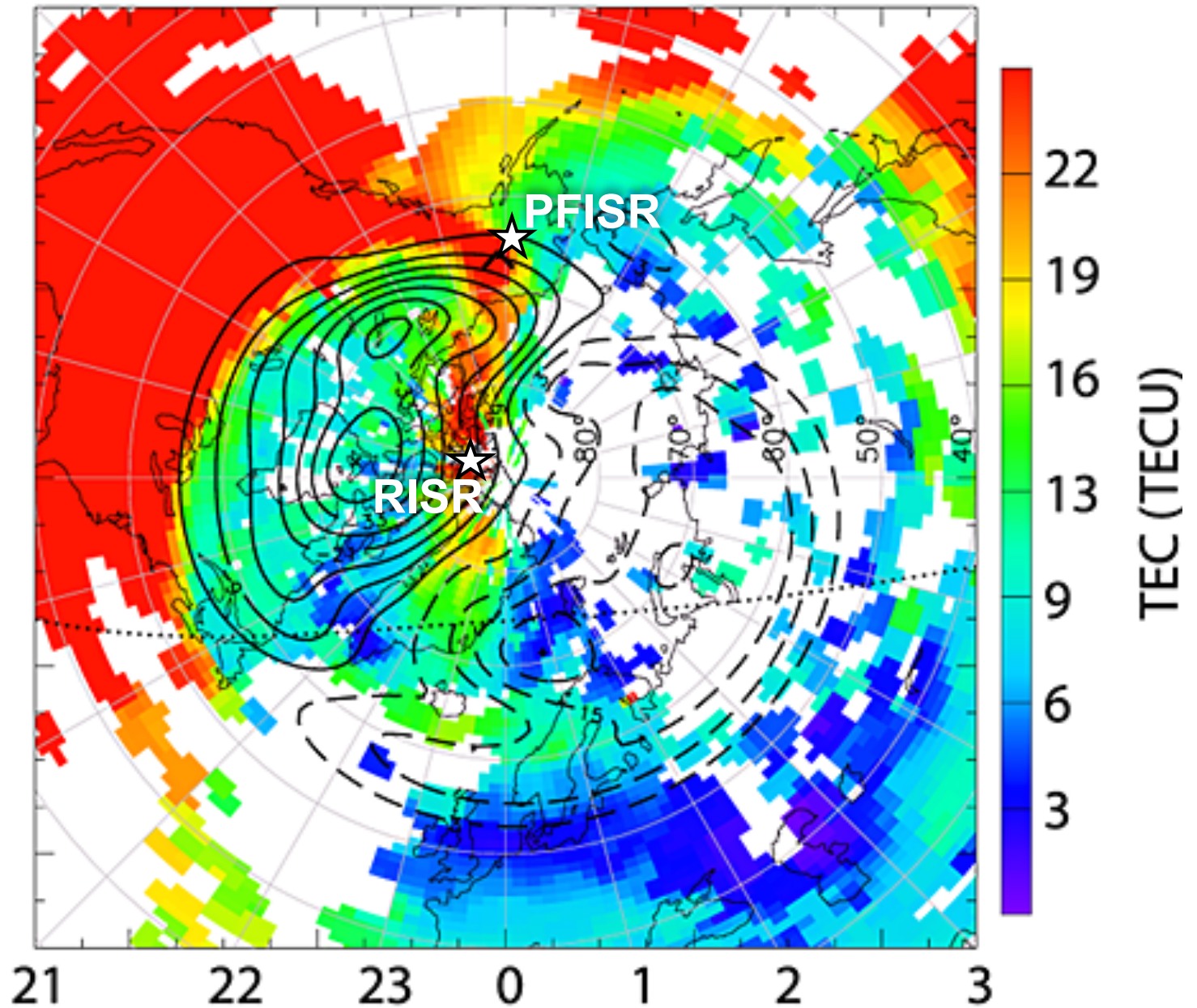
# Birkeland currents



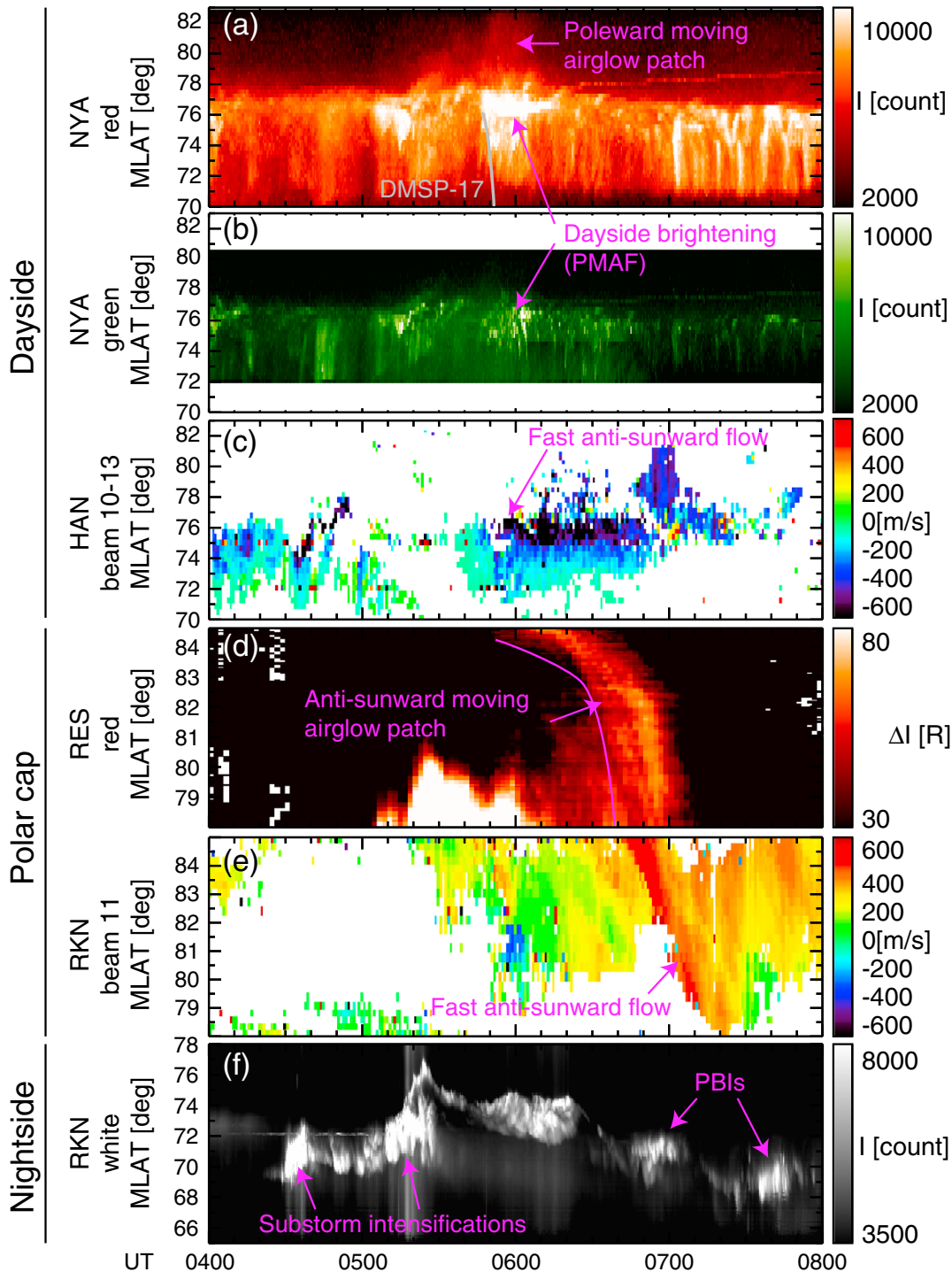
**Electromotive force needed to drive convection**

*Ijima and Potemra, 1976*

# What we need: 1) Better coverage



2011 Nov 27



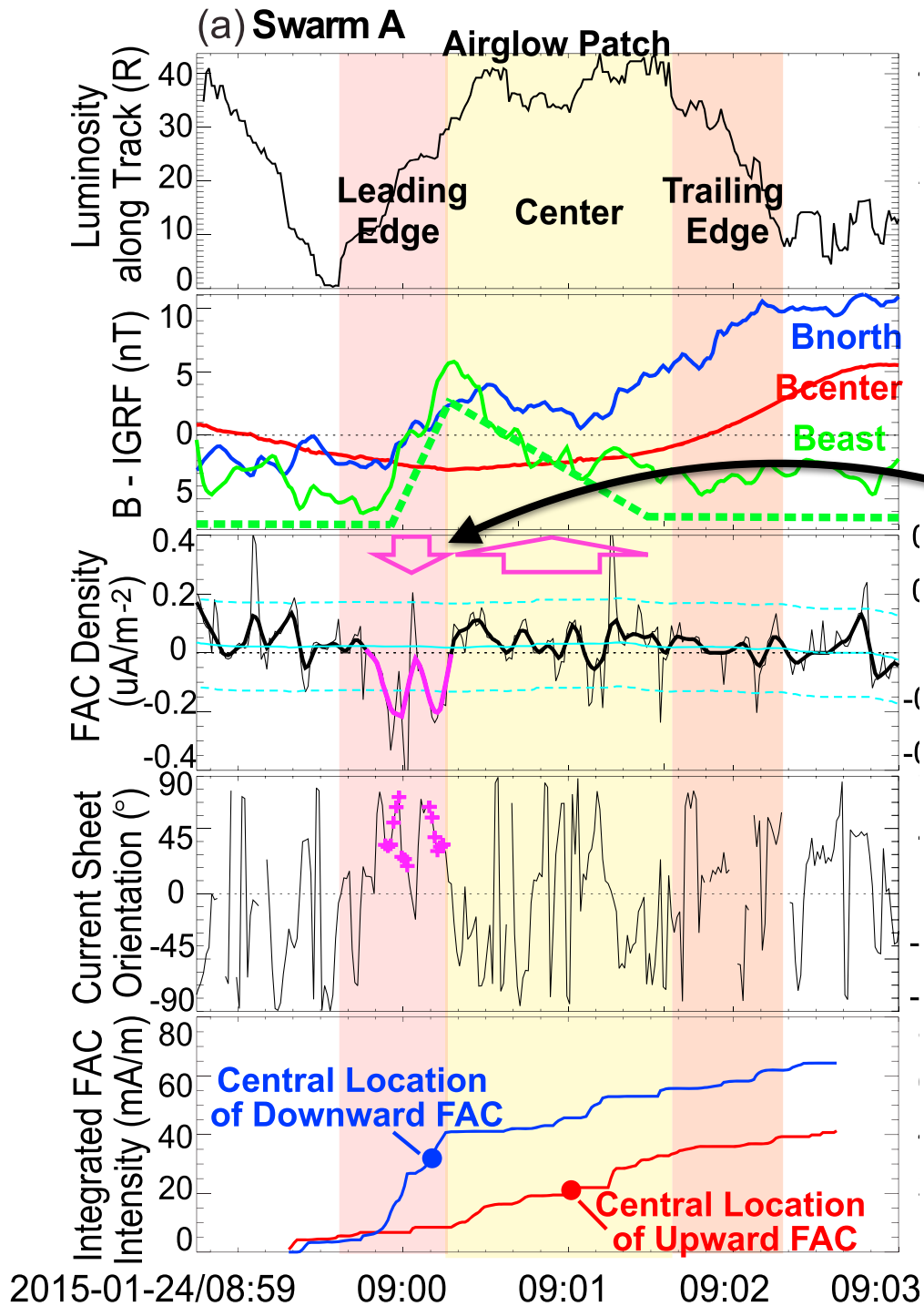
Patch of enhanced plasma density moves poleward from dayside.

...accompanied by a poleward moving auroral form (reconnection)

HF radar measures fast poleward flow channel

Measurements at geomagnetic pole show patch riding in a high speed flow field

On the nightside, flows appear to cause auroral intensifications along the auroral oval



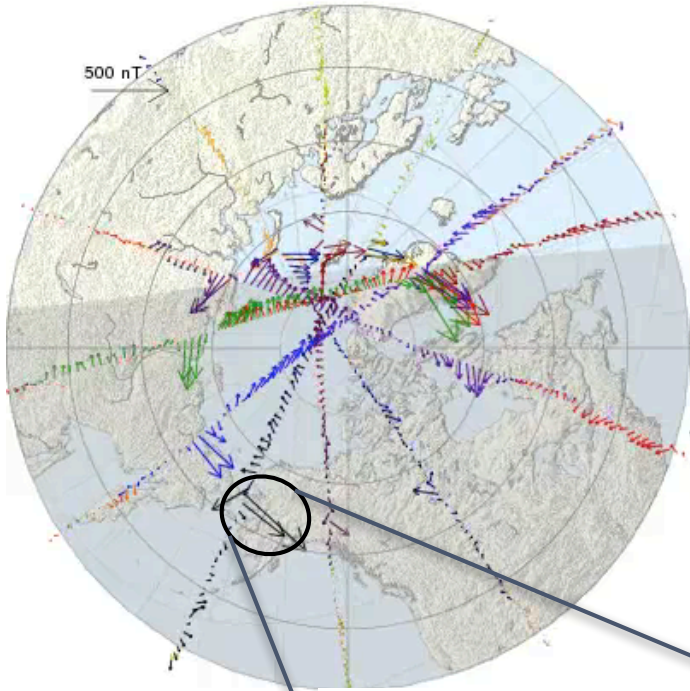
Conjugate measurements from SWARM satellite constellation suggests that anomalous flow channel is powered by enhanced field aligned currents.

**Such studies should be much easier to carry out, with clarity of results unaffected by observational limitations.**

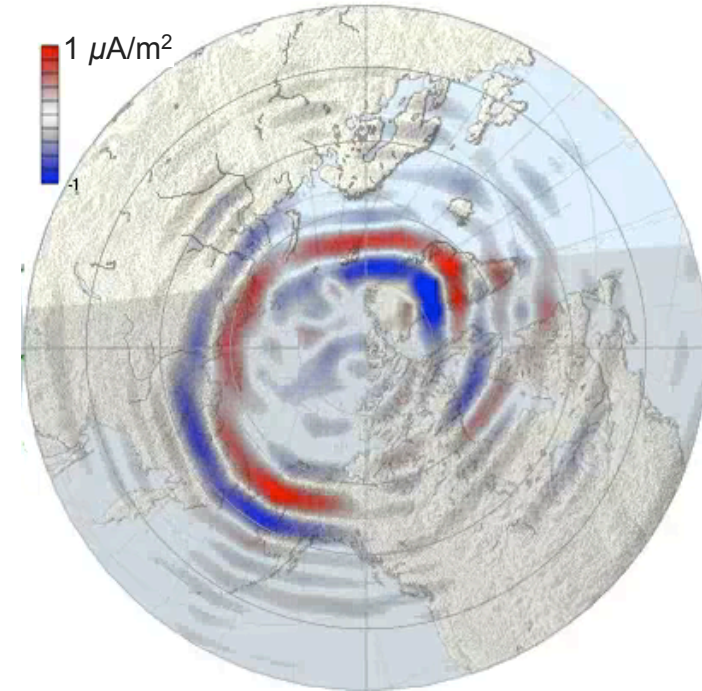
# What we need: 2) Multi-scale observations

01 Mar 2011 10:04:00 - 10:14:00 UT

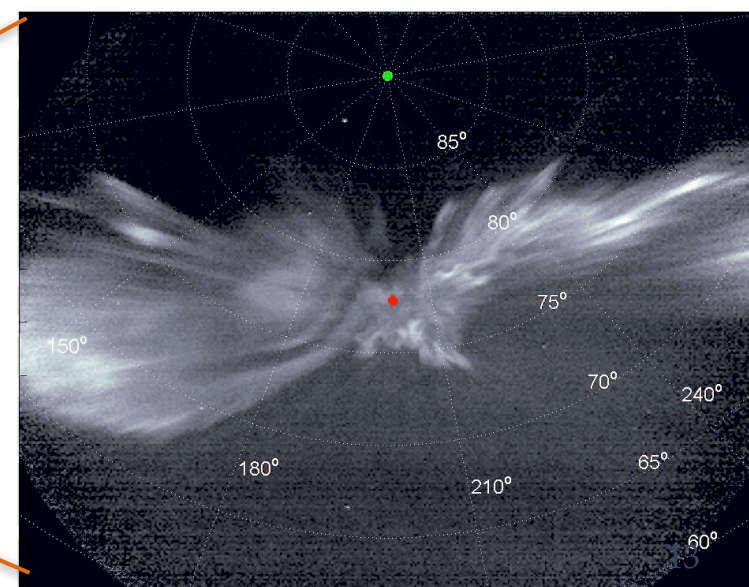
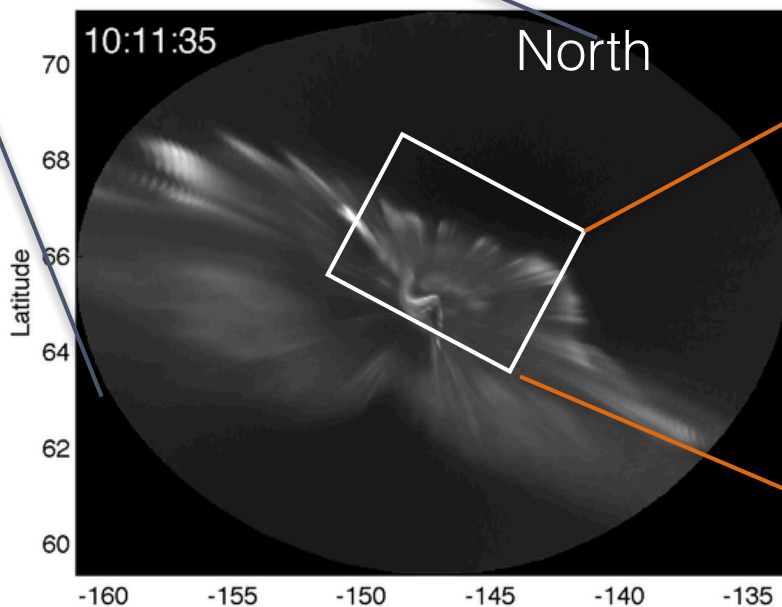
(north)



Spherical harmonic expansion

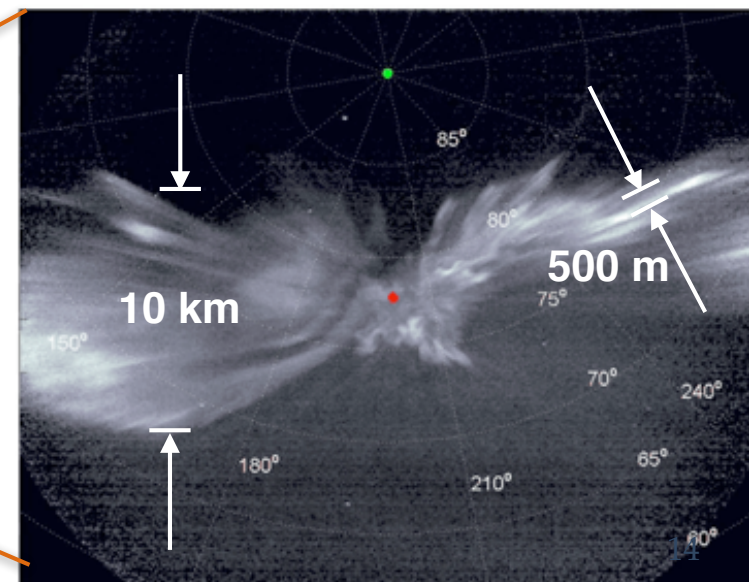
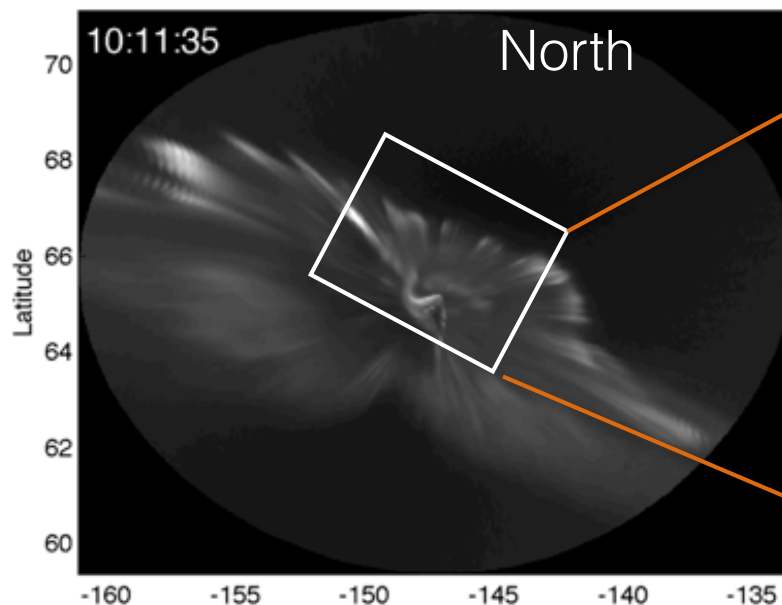
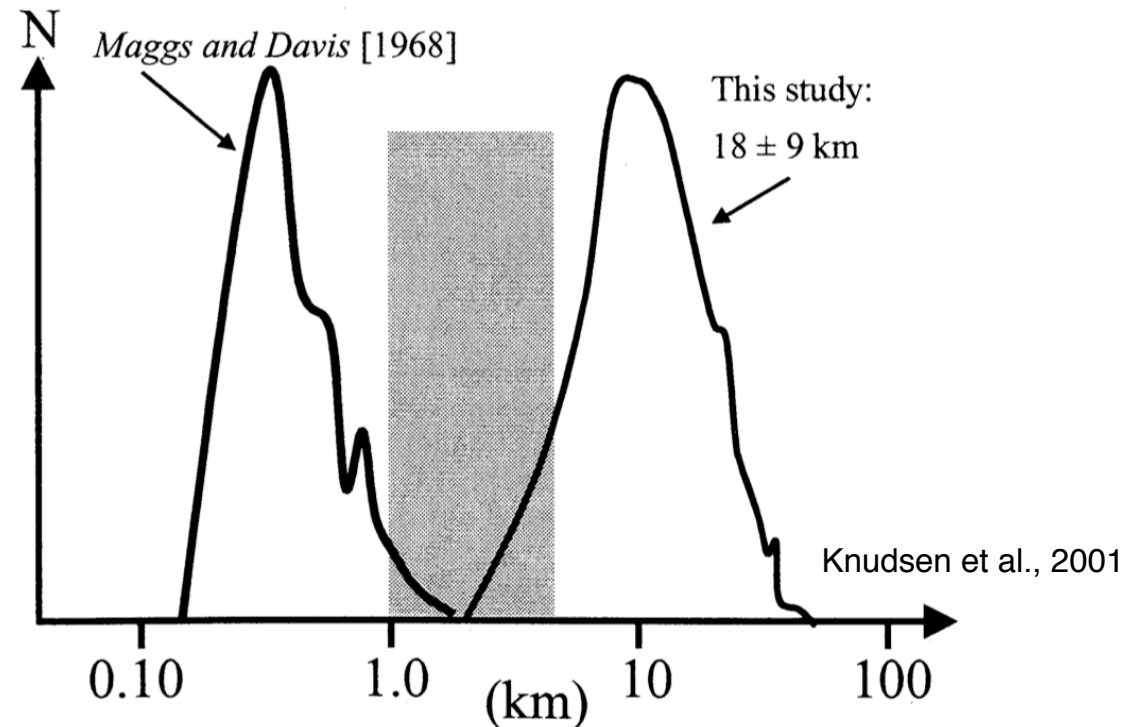


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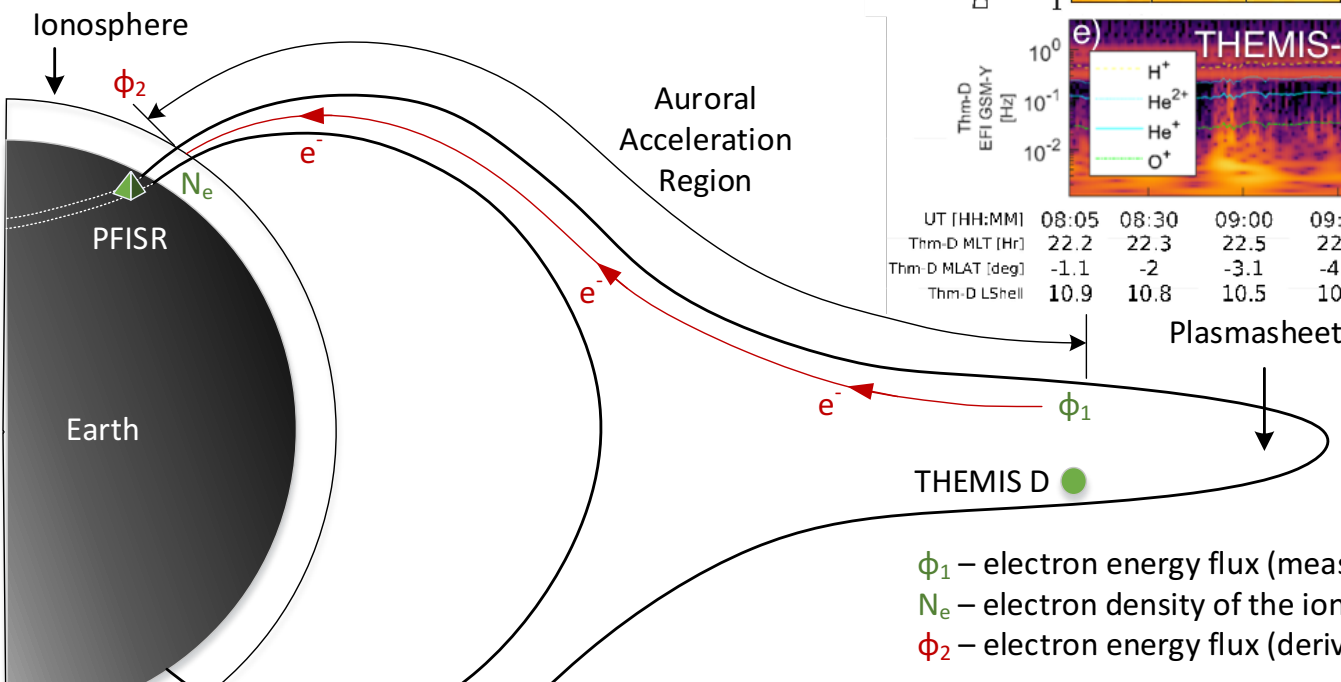
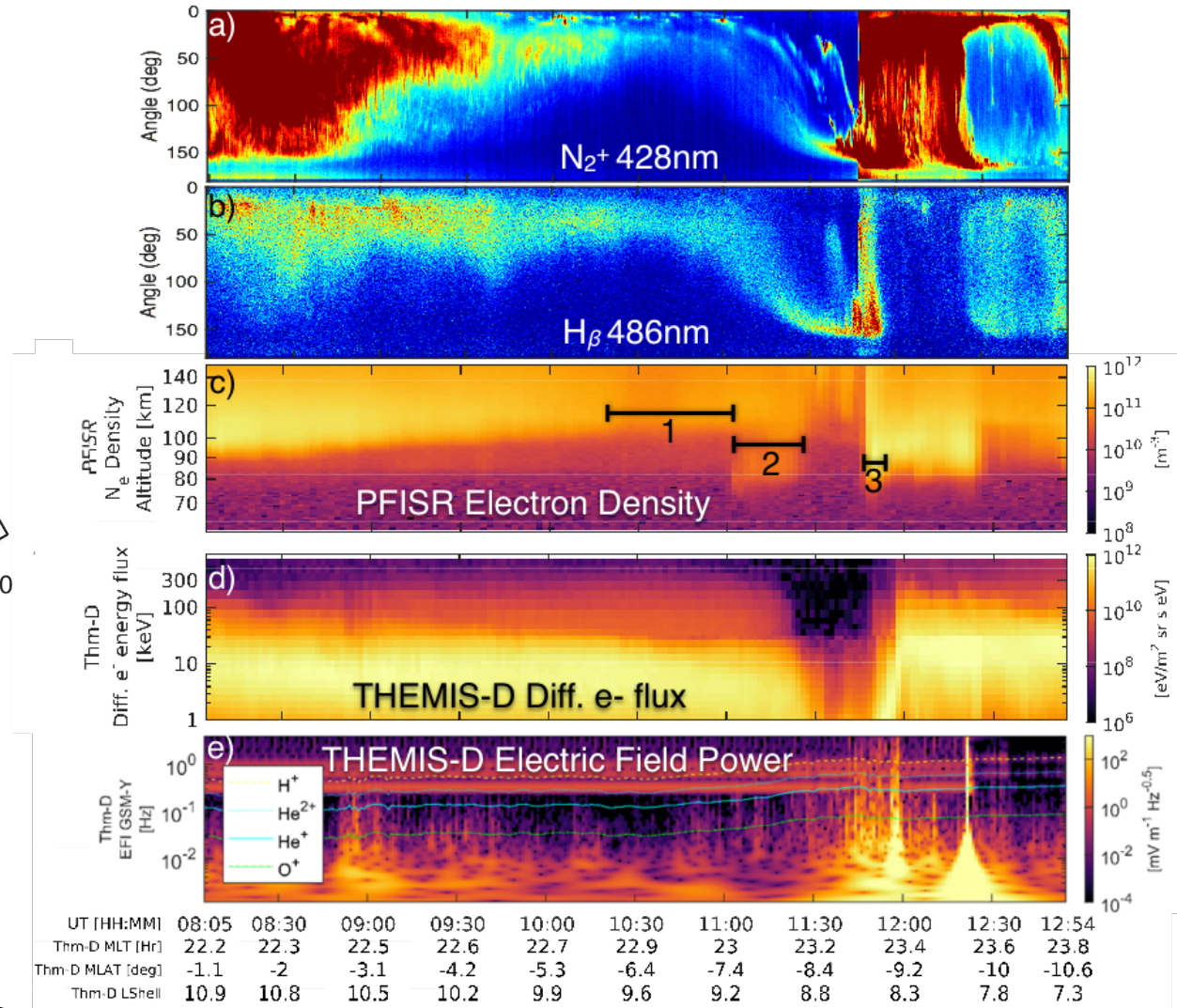
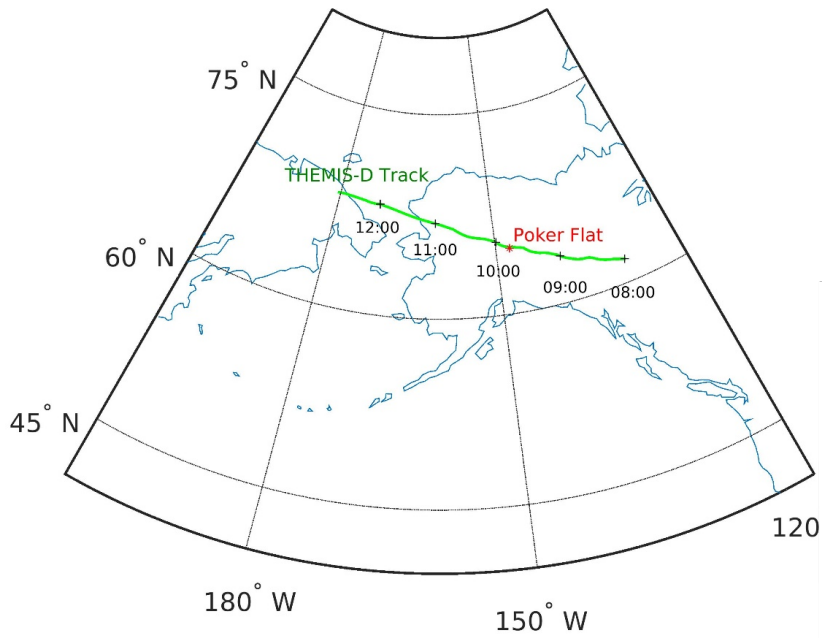


# What we need: 2) Multi-scale observations

There is not a continuum of scales in the magnetosphere-ionosphere system. Rather, the physics changes abruptly as we cross specific parameter regimes.

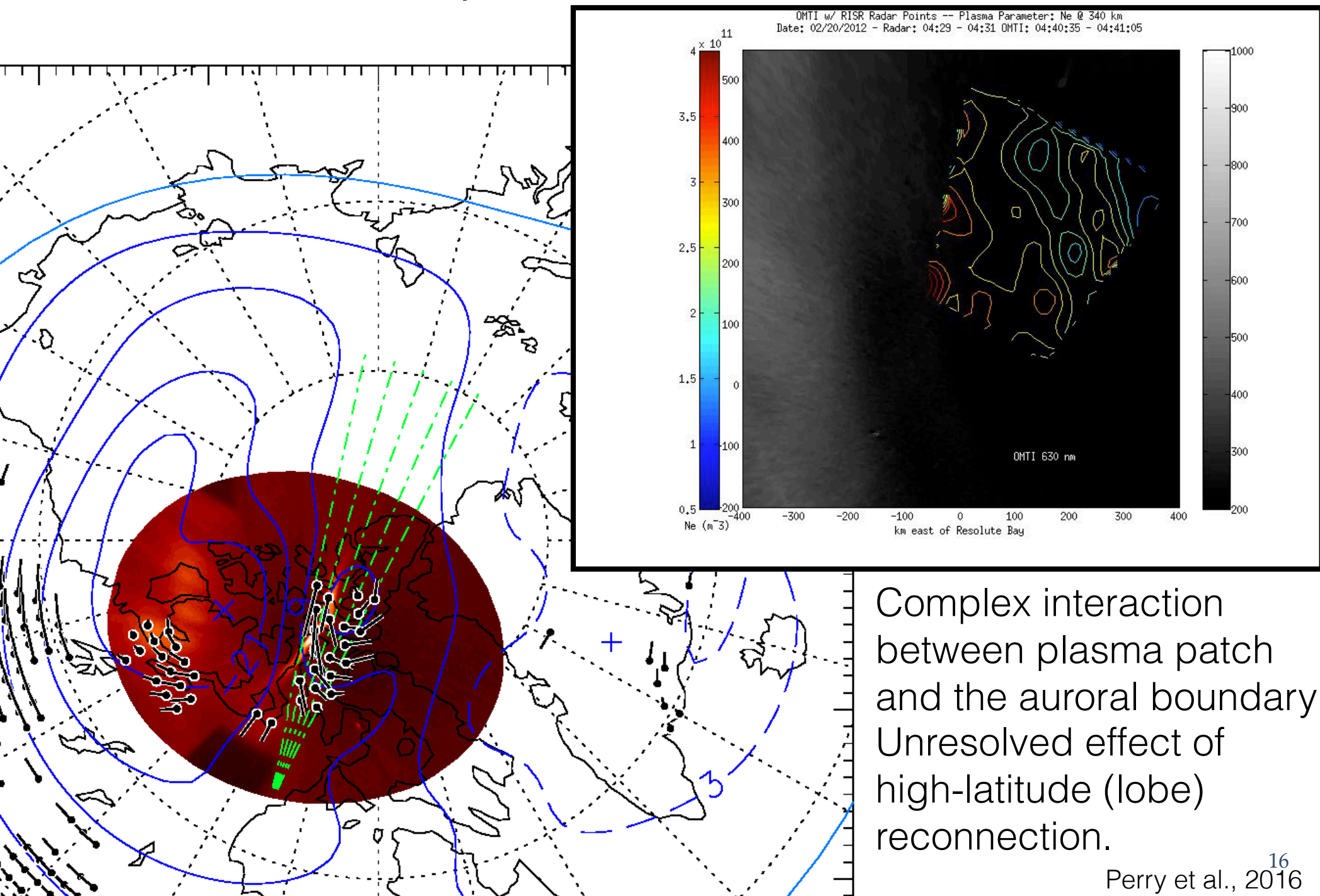


# What we need: 3) Collaborative measurements from ground and space



- $\phi_1$  – electron energy flux (measured by THEMIS D)
- $N_e$  – electron density of the ionosphere (measured by PFISR)
- $\phi_2$  – electron energy flux (derived from  $N_e$ )

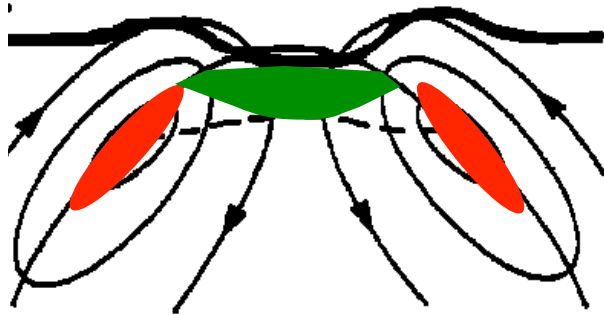
# What we need: 4) Creative experimental techniques



Complex interaction between plasma patch and the auroral boundary  
Unresolved effect of high-latitude (lobe) reconnection.

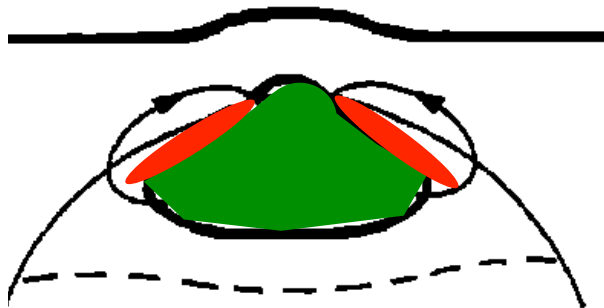


# What we need: 4) Creative experimental techniques

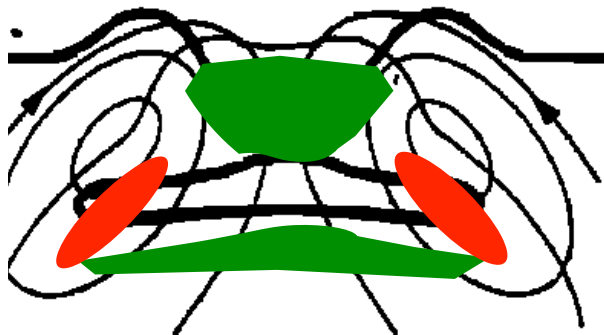


 **E-region arc**

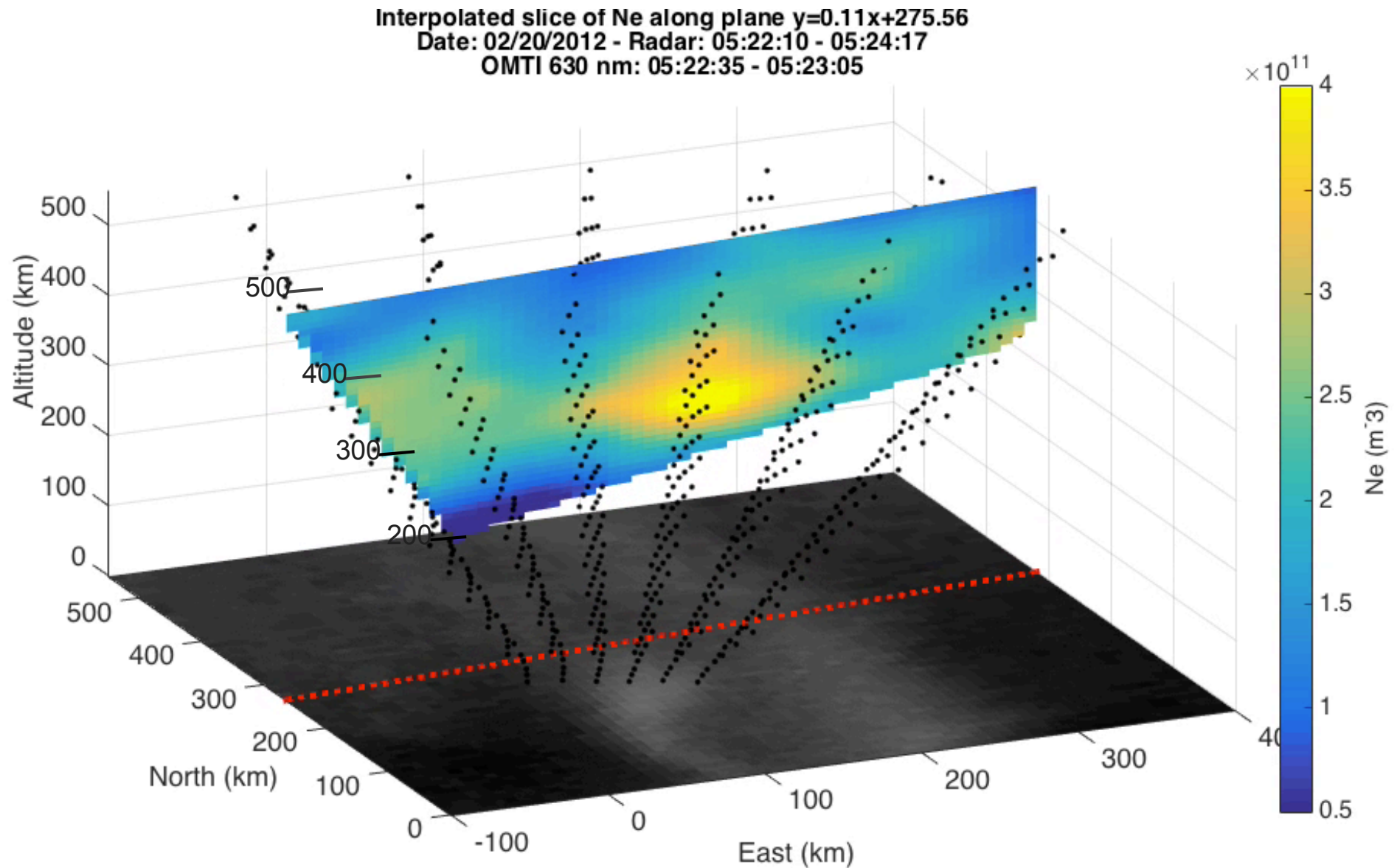
 **F-region patch**



Temporal scales,  
spatial scales, and  
flow complexities  
associated with this  
physics has not been  
established.

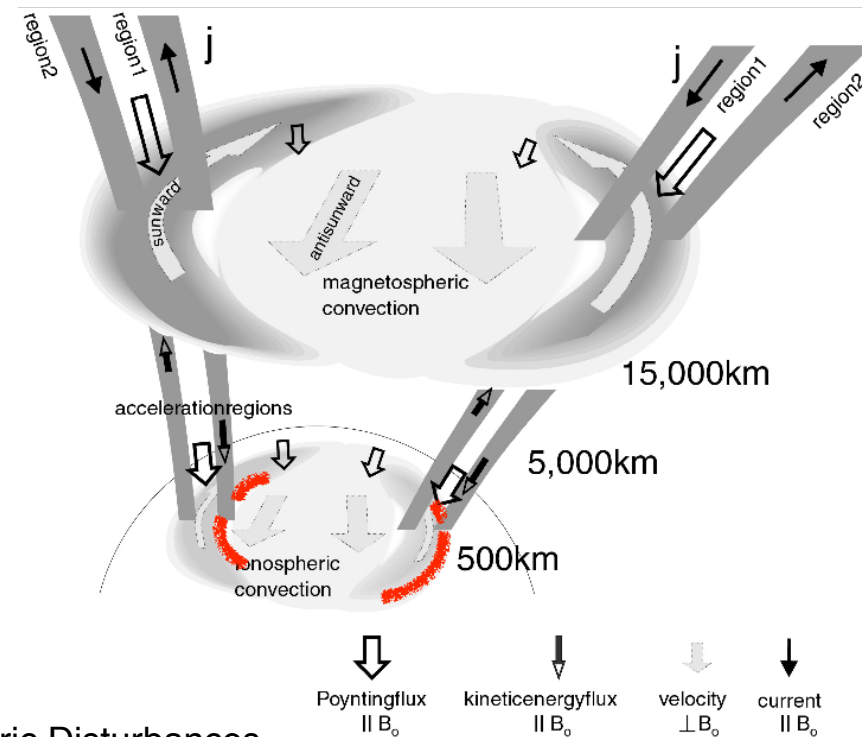


# What we need: 4) Creative experimental techniques



# What we need

- 1) Better coverage
- 2) Multi-scale observations and multi-scale modeling
- 3) Collaborative measurements from ground and space
- 4) Creative experimental techniques



Join us for further further discussion:

Monday 1600-1800: A. Space Weather Observation Network I: Ionospheric Disturbances

Tuesday 10-12: B: Space Weather Observation Network I: Ionospheric Disturbances

Tuesday 13:30-15:30: A: Space Weather Observation Network II: Thermospheric Expansion

Wednesday 13:30-15:30: B: Space Weather Observation Network II: Thermospheric Expansion